UCLouvain

lphmd2357

2024

Computational and Numerical Methods for Medical Physics

4.00 credits	24.0 h + 10.0 h	Q1

Teacher(s)	Lee John ;Sterpin Edmond ;
Language :	English
Place of the course	Louvain-la-Neuve
Main themes	This course aims to familiarize the student with the computational and numerical methods frequently used in Medical Physics, like Monte Carlo simulations, with their physical and statistical underlying concepts, as well as to provide the basis of Artificial Intelligence, Machine Learning, and Deep Learning techniques and their use to solve data-driven problems.
Learning outcomes	**At the end of this learning unit, the student is able to :** The specific learning outcomes are: • The student is able to apply advanced statistical methods needed in Medical Physics. • The student acquires the computational and calculation skill to address quantitatively common problems in Medical Physics. • The student solves classification and regression problems in Medical Physics by applying Machine Learning and Artificial Intelligence techniques like decision trees, random forests, neural networks, deep learning, ... to various types of data, including medical images. • The student understands and masters the basic aspects of optimization methods that underpin most of the aforementioned techniques.
Evaluation methods	Type : Partial or continuous assessment with (final) exam during the examination period Description of evaluation : Oral, Report • Exam during the examination period: 70% of the total score. • Reports on the assignments of selected exercises: 30% of the total score.
Teaching methods	Lectures For each part of the course (statistics, Monte Carlo techniques, Machine Learning) a series of exercises is proposed. They should be solved by using the adequate computing material.

Content	The course will be organized around three main pillars
	• Advanced Statistics in Medical Physics: statistics are heavily used in medicine in general and in medical physics in particular. This includes statistical significance of laboratory and clinical experiments; quantification of risk; estimation and propagation of uncertainties (type A and type B uncertainties); probabilistic problem solving.
	• Monte Carlo techniques. Monte Carlo engines are often used as black box in clinical practice and R&D. The goal is to provide insights in the theoretical grounds of Monte Carlo simulations and also in the practical specificities of modern implementations. This includes: random number generation; sampling techniques (inverse transform, rejection technique); variance reduction; statistical error estimation (direct or batch technique); problem definition (geometry and materials); use of specialized hardware (many-core processors and GPU). Practical examples and important results are illustrated in radiotherapy, nuclear medicine and radiology.
	• Introduction to Machine Learning:
	  • Context and purpose of Artificial Intelligence, Machine Learning, and Deep Learning.
	  • The various types of learning problems (supervised, non-supervised, reinforcement, transfer).
	  • The various types of data sets and their purpose (training, validation, test).
	  • Short introduction to optimization.
	  • A few techniques:
	    • Principal component analysis, linear discriminant analysis.
	    • Decision trees and random forests.
	    • Support Vector Machines.
	  • Neural networks, from single artificial neuron to deep (convolutional) networks.oInterpretation of the results (ROC curve/sensitivity/specificity/...).
	  • Specifics of data collection for AI/ML/DL in medical physics (access to patient data and the importance of consistent patient data; how to guide efforts in structured reporting).
	  • Big data and data preprocessing (images, radiomics,..).

Faculty or entity in charge	PHYS

Programmes containing this learning unit (UE)

Program title	Acronym	Credits	Prerequisite	Learning outcomes
Master [120] in Medical Physics	PHMD2M	4		